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(54) **Title:** APPARATUS FOR RECORDING ON AND/OR RETRIEVAL FROM FLUORESCENT OPTICAL CLEAR CARD

(57) **Abstract:** There Is disclosed a random-access light-emitting dot matrix used for data writing process. The number and disposition of dots in the matrix is the same as the number and disposition of pits on one page of one information layer of the fluorescent multi-layer optical card. Written information can be retrieved page by page.

APPARATUS FOR RECORDING ON AND/OR RETRIEVAL FROM FLUORESCENT OPTICAL CLEAR CARD

THE FIELD OF THE INVENTION

This invention relates to optical memory systems for recording and/or retrieval information and more particularly, to fluorescent multi-layer optical card.

THE BACKGROUND OF THE INVENTION

The existing optical memory systems utilize two-dimensional data carriers with one or two information layers. Most of previous technical solutions in optical data recording propose registration the changes in reflected laser radiation intensity in local regions (pits) of the information layer. These changes could be a consequence of interference effects on the relief of optical discs of CD or DVD ROM-type, burning of holes in the metal film, dye bleaching, local melting of polycarbonate in widely-used CD-R systems, change of reflection coefficient in phase-change systems, etc.

Three-dimensional, i.e. multi-layer, optical storage systems provide comparatively higher storage and recording capacity. However this imposes specific limitations on and requirements to the design and features of optical information carrier, ways of data recording and reading, especially in the depth of the carrier.

In reflection mode every information layer of the multi-layer optical information carrier should possess partly reflective coating. It reduces intensity of both reading and reflected information beam because of passing through media to the given information layer and back to the receiver.

Besides, due to their coherent nature, both beams are subject to hardly estimated diffraction and interference distortions on fragments (pits and grooves) of the information layers on their way.

Multi-layer fluorescent optical information carriers with fluorescent reading are preferable as they are free of partly reflective coatings.

Diffraction and interference distortion in this case will be much less due to non-coherent nature of fluorescent radiation, its longer wavelength in comparison with the reading laser wavelength, and transparency and homogeneity (similar refractive indices of different layers) of the optical media towards the incident laser and the fluorescent radiations. Thus, multi-layer fluorescent carriers have some advantages over reflective ones.

The system based on an incoherent signal (fluorescence, luminescence) has twice as high spatial resolution as coherent methods (reflection, absorption or refraction) (see Wilson T., Shepard C. "Theory and Practice of Scanning Optical Microscopy", Academic Press, London, 1984). Using the incoherent signal the multi-layer optical memory one can get as high as eight times increasing of information capacity.

SUMMARY OF THE INVENTION

Thus, there is provided in the present invention random-access light-emitting dot matrix used in the writing process. There are several ways to realize such light source: matrix of light emitting diodes (LED) (solid-state or organic) or matrix of vertical cavity surface emitting lasers (VCSEL) integrated with computer-controlled microelectronic circuitry, as well controllable transparency or controllable matrix of micro mirrors spatially modulating the external laser beam]. The number and disposition of dots in the matrix is the same as the number and disposition of pits on one page of the FMC information layer. The actuator-driven micro lens forms the image of the dot matrix on the selected page. During writing only those dots are switched on that correspond to "1"-bits. To focus on another page in the same column, the micro lens is moved perpendicular to the FMC plane. To focus on another page in the same layer, the Clear Card itself is moved.

Written information can be retrieved page by page from the fluorescent signal. To initiate fluorescence one column of pages is illuminated by emission of the light source (laser or LED) of the appropriate wavelength. The magnified image of the requisite page is generated on the receiving surface of the CCD camera using a micro lens and a semitransparent mirror. To attain maximum contrast of the CCD camera output signal, the illuminating emission must be filtered. For this purpose a dichroic mirror with the appropriate spectral pass band may be used. Another possibility to filter illuminating emission is to use a polarizer or Notch filter based on liquid crystal instead of the dichroic mirror.

BRIEF DESCRIPTION OF THE DRAWINGS

These constructional features and advantages of the invention will become more clearly understood in the light of the ensuing description of preferred embodiments thereof, given by way of example only, with reference to the accompanying drawings, wherein -

Fig. 1 is a schematic representation of one of the preferred embodiments of the fluorescent multi-layer optical clear memory card;

Fig. 2 is one of possible embodiments of parallel reading-writing mode device using the fluorescent multi-layer information carrier; and

Fig.3 is another embodiment of data reader-writer using the fluorescent multi-layer information carrier.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Below a description of the present invention is given with reference to accompanying drawings.

Fig. 1 schematically presents one of the variants of Fluorescent Multi-layer Card (FMLC) 10 comprising the following basic components: rectangular parallelepiped-like thick substrate 11, fluorescent multi-layer information carrier (FMC) 12 and protection layer 20 to protect the optical recording system from mechanical damage and aggressive media.

Substrate 11 is a nontransparent plastic plate designated for mechanical fixing of FMC 12 and mounting of FMLC 10 in the reader-writer. For the case when the unit forming reading radiation and the unit recording fluorescent information signal in the reader are disposed on different sides of FMLC, insert 13 made of optically transparent material is provided at the location of FMC 12. Holes 14 serve for precise positioning of FMLC in the reader-writer. FMC 14 is made as a multi-layer structure wherein fluorescent information carrier layers 18, 0.1-1 μm thick, are separated by reader-, writer- and fluorescence-transparent radiation polymer layers 10-70 μm thick. To prevent spurious reflection on the boundary of layers 18 and 19, their refraction indices are preferably chosen equal within the wavelength range of the above-mentioned types of radiation.

For the WORM (write once – read many) mode operation, the information carrier waves are photosensitive and contain uniformly distributed at the molecular level photosensitive and other components, among them non-fluorescing dye precursors, photochemically generating colored fluorescing dyes or compositions loosing their fluorescing properties under the action of writing radiation.

In accordance with the present invention, information is read page-by-page using, for instance, a CCD camera, at the velocity of the order of 0.1-0.001 frame/s. This enables utilization of luminophores with long-life excitation state including organic lumonophores with long-life phosphorescence, excimers and exciplexes with long-life luminescence as well as inorganic compounds.

The recorded data are stored as a multitude of pages 15 comprising a host of individual fluorescing marks 17 (analogs of reflecting pits in known CD- or DVD-ROM), disposed along rectilinear tracks 16.

In addition to information layers wherein WORM information is recorded, FMC can also include ROM address layers with service information recorded, such information is particularly designated for positioning of the reading head relative to FMC.

Several pages located at different information layers one above another form a "pile of pages" or an information "frame". From said frame data can be retrieved without mechanical displacement of the reading head in the FMC plane by means of refocusing of the lens from one page located in one layer to another one located in another layer. The FMC address layer serves for centering of the frame and is either the first or the last layer within FMC volume.

In the present invention, a random-access light-emitting dot matrix is used for data reading. (There are several ways to implement such source of light: matrix of light-emitting diodes (LED) – solid-state or organic – or matrix of vertical cavity surface emitting lasers (VCSEL) integrated with computer-controlled microelectronic circuitry, as well as a controllable transparency or controllable matrix of micro mirrors spatially modulating the external laser beam.) The number and disposition of dots in the matrix is the same as the number and disposition of pits on one FMC page. The actuator-driven lens forms the dot matrix image on the selected page. During writing, only those dots are switched on that correspond to "1"-bits. To focus on another page in the same column, the lens is moved perpendicular to the FMC plane. To focus on another page in the same layer, the Clear Card itself is moved.

A possible version of apparatus with parallel (page by page) data recording and retrieval on Clear Cards is shown in Fig. 2. Recording of information on pages in FMC photosensitive layers is enabled through the use of LED or VCSEL matrix 21 as a light source. The matrix is driven by microelectronic IC 22 controlled by computer 23. The number and disposition of Leds (VCSELs) in the matrix corresponds to the number and disposition of information pits on one FMC page. During writing, LEDs (VCSELs) corresponding to "1" pits are switched on. The reduced image of the light-emitting dot matrix is generated on the desired FMC page by aspheric lens 24. To write information on another page in the same layer, the clear card itself is moved by actuator 26 in X- or Y-direction.

To ensure reasonable power consumption of the light-emitting dot matrix and reasonable size of the entire device, divergence of the beam in each emitter should be small enough. The VCSEL having a diffraction-limited output beam meets this requirement. The LED matrix needs a corresponding micro lens matrix to condense output emission.

For example, if the diameter of each information pit is 0.5 μm, the spatial period of pits disposition in the 500x500 page is 1 μm and the magnification of the optical system is x20, then the diameter of each emitter is 10 μm and its size is 1.0x1.0 cm. The total number of emitters (pits) is 250 000.

For VCSELs of visible spectral range with a 10-μm aperture, the beam divergence depending on the wavelength is several angular degrees. To form similar beam divergence of LED a condensing micro lens is required. The condensing LED diameter must be significantly smaller than the lens diameter (10 μm in this example). The best specimens if visible LEDs having their external efficiency of more than 10% permits obtaining about 100 nW CW output power from 2 μm in diameter emitting surface. The matrix of such LEDs with 20-micron spatial period integrated with corresponding matrix of micro lenses of 10-micron diameter meets the requirements for the proposed apparatus. Assuming even 90% loss in the optical system, it corresponds to 10 nW per pit (about $5W/cm^2$). For photosensitive material with the absorption cross-section of 10^{16} cm^2, such power density of illumination permits one to obtain a recording bit rate of about 1 Gbit/sec using the proposed method.

The total power consumption of the LED matrix in this case will be of the order of 0.10 W. Taking into account its size, no special cooling system is necessary.

The theoretical estimations show that using this method and photosensitive materials with linear response, information can be written in FMC-R containing up to 10 layers. For materials there are practically no limitations for the number of layers.

Written information can be retrieved page by page. To initiate fluorescence one column of pages is illuminated by emission from light source (laser or LED) 27 of the appropriate wavelength. If necessary 100% mirror 28 can be used. The magnified image of the needed page is formed on the receiving surface of CCD camera 29 using lens 24 and semitransparent mirror 200. To obtain maximum contrast of the CCD camera output signal, the illuminating emission must be filtered. For this purpose dichroic mirror 201 with an appropriate spectral pass band may be used. The fluorescent emission from pits is not polarized. Another possibility to filter illuminating emission of pits is to use a polarizer instead of mirror 201. If the illuminating beam is not fully polarized another crossed polarizer can be inserted (not shown in Fig.2).

The necessary condition in this case is isotropism of the molecules disposed in the FMC information marks to ensure luminescence isotropism even under the action of polarized reading radiation. In this case the reading beam incident on the photo receiver will be switched off (absorbed) by the analyzer while partially absorbed nonpolarized luminescent radiation will pass via the analyzer to the photoreceiver.

Another possibility is to apply a Notch liquid crystal filter as spectral one.

One more version of random-access light-emitting dot matrix is schematically shown in Fig.3.

The controllable light-emitting matrix can be also implemented on the basis of microoptoelectromechanical system (MOEMS) representing a matrix of micro mirrors 30 with electrically controllable position on the corresponding piezo crystal matrix. Said matrix in turn is integrated with electronic control circuit 31. Depending on the driving signal from computer 32, in matrix elements the mirrors that have received signal “1” are disposed at a different angle as compared to the mirrors that have received signal “0”. If said matrix is illuminated by a parallel light beam, then lens 33 of the above-mentioned system can be positioned in such a way that only beams reflected from the matrix elements that received signal “1” will get in the aperture.

Coming back to the geometry and power assessments of the example discussed above and assuming that the mirrors occupy 25% of the total matrix area and have their reflection coefficient about 100%, it follows that to achieve 10 nW/pit in the recording mode, a 150 mV homogeneous uniform light beam about 15 cm in diameter will be needed. To this end, many laser types of different spectral ranges can be utilized. In particular, there exist miniature laser diodes enabling the above-mentioned CW power in spatial single-mode operation. To generate the requisite beam, beam circularizer-expander 35 should be placed behind laser 34.

While the above description contains many specificities, these should not be construed as limitations on the scope of the invention, but rather as exemplification of the preferred embodiments. Those skilled in the art will envision other possible variations that are within its scope. Accordingly, the scope of the invention should be determined not by the embodiment illustrated, but by the appended claims and their legal equivalents.

WHAT IS CLAIMED IS:

1. An apparatus for recording and retrieval of information on/from the fluorescent optical card comprising

-a card holder;

-a device for moving the cards relative to the writing/reading beams;

-a controllable light-emitting dot matrix for writing information on the card;

-an illuminating light source for reading information from the card;

-a photoreceiver for reading information from the card; and

-an optical system to form an image of light-emitting dot matrix on the information pages of the card and to form an image of the information pages of the card on the input surface of the photoreceiver.

2. The apparatus of claim 1, wherein recording of information is produced in parallel mode of operation (page by page).

3. The apparatus of claims 1 and 2, wherein the random-access light-emitting dot matrix is used as a light source for recording information.

4. The apparatus of claims 1 and 3, wherein the number and disposition of dots in the light-emitting dot matrix corresponds to the number and disposition of information pits on one page of the card.

5. The apparatus of claims 1, 3 and 4, wherein the light-emitting diode (solid-state or organic) matrix is used as a light-emitting dot matrix.

6. The apparatus of claims 1 and 5, wherein the light-emitting diode matrix is integrated with the driving microelectronic integral circuitry and matrix of condensing micro lenses.

7. The apparatus of claims 1, 3 and 4, wherein the matrix of vertical cavity surface emitting lasers is used as a light-emitting dot matrix.

8. The apparatus of claims 1, 3 and 4, wherein said matrix of vertical cavity surface-emitting lasers is integrated with the driving microelectronic integral circuitry.

9. The apparatus of claims 1, 3 and 4, wherein the laser and controllable transparency are used as a light-emitting dot matrix.

10. The apparatus of claims 1, 3 and 4, wherein the laser or controllable matrix of micro mirrors is used as a light-emitting dot matrix.

11. The apparatus of claim 1, wherein the actuator-controlled lens forms the image of said light-emitting dot matrix on the selected page of the card.

12. The apparatus of claim 1, wherein during the recording process only those light-emitting dots are switched on that correspond to "1"-bits.

13. The apparatus of claim 11, wherein switching over to the other page in the same column is provided by lens moving perpendicular to the card plane.

14. The apparatus of claims 1 and 11, wherein switching over to the other page in the same column is provided by moving of the card itself in the perpendicular to the optical axis of lens direction.

15. The apparatus of claim 1, wherein the retrieval of information is produced in parallel operation mode (page by page).

16. The apparatus of claim 1, wherein the coupled charge device camera is used as a photoreceiver.

17. The apparatus of claim 1, wherein the illuminating light during information retrieval is filtered to ensure that only fluorescent (information carrying) light reaches the photoreceiver.

18. The apparatus of claims 1 and 17, wherein the dichroic mirror is used as a spectral filter.

19. The apparatus of claims 1 and 17, wherein the Notch filter based on liquid crystals is used as a spectral filter.

20. The apparatus of claims 1 and 17, wherein polarizer(s) is (are) used for filtering the illuminating light.

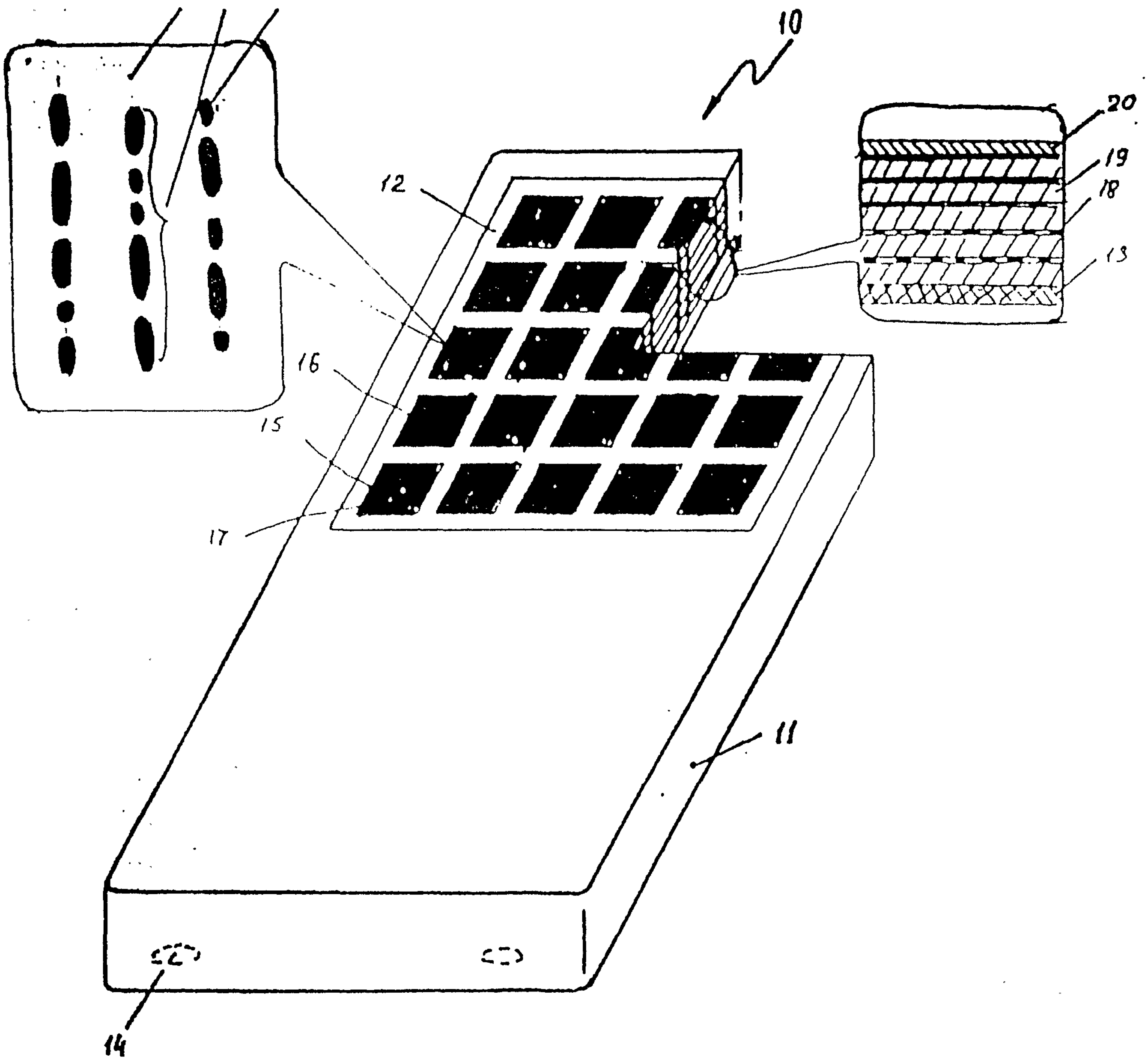

Fig. 1

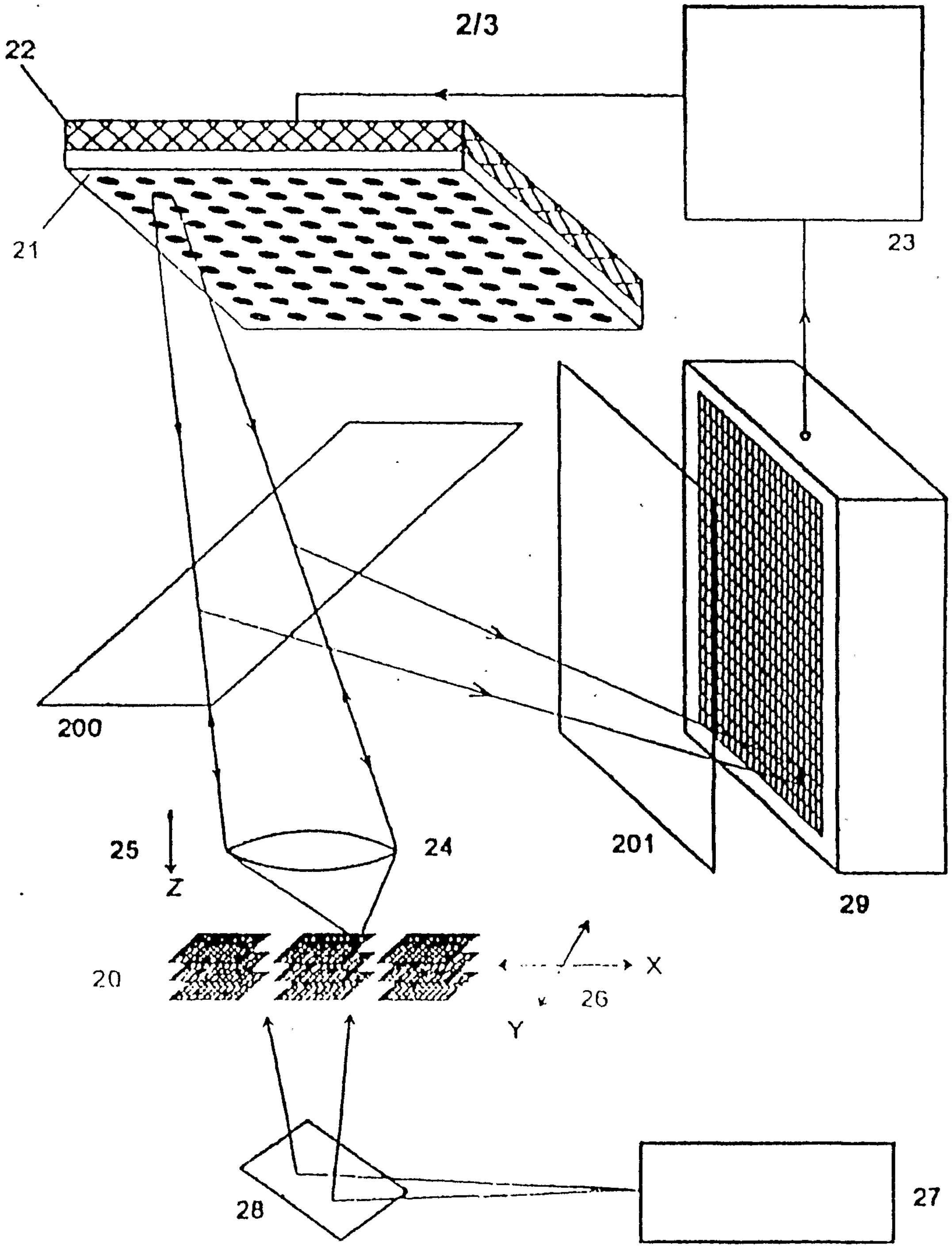

Fig.2

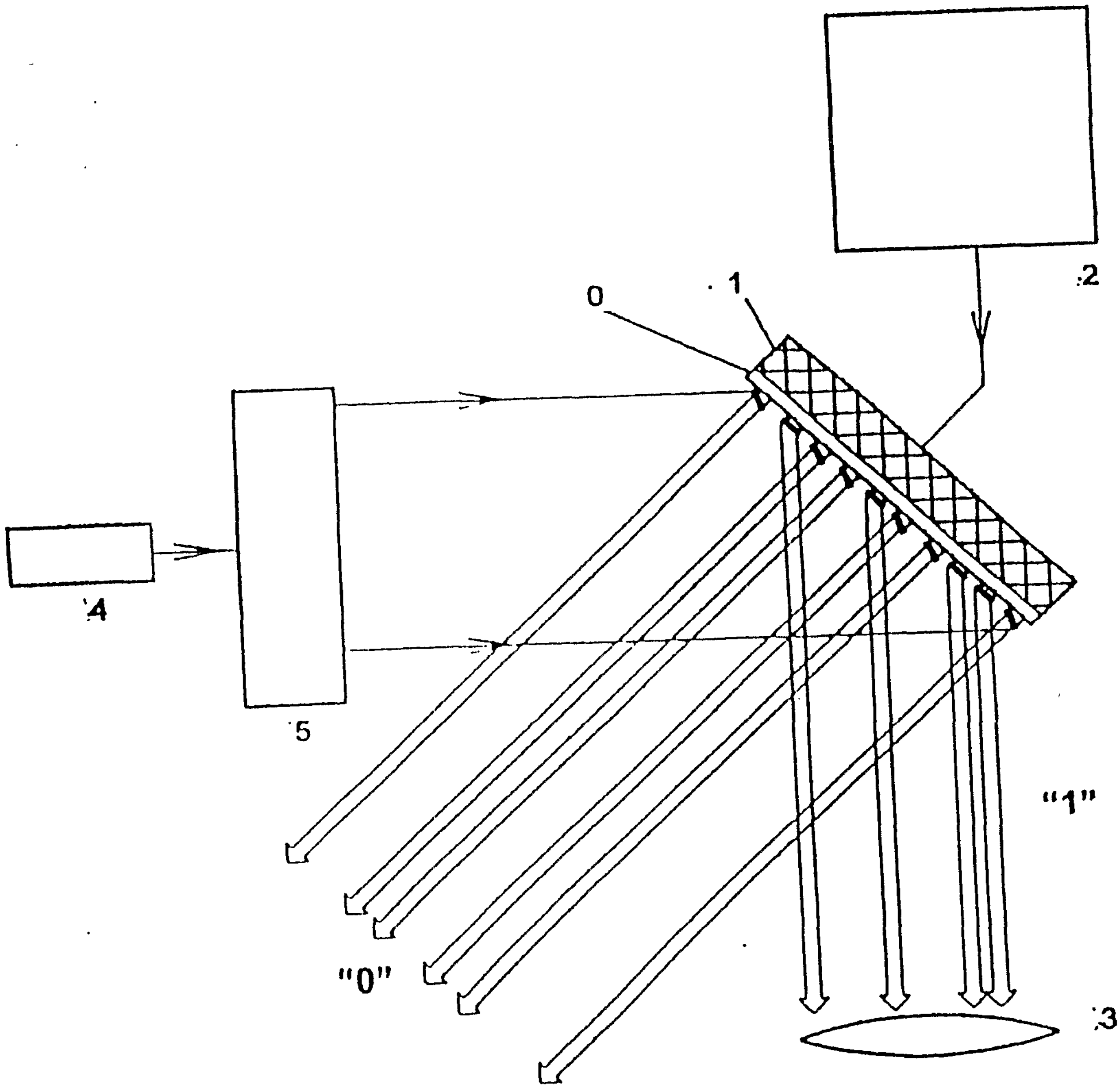

Fig.3